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Title: Antarctic ice shelf-ocean interactions in high-resolution, global simulations using the Energy Exascale Earth System Model (E3SM) Part 1: Configuration and evaluation

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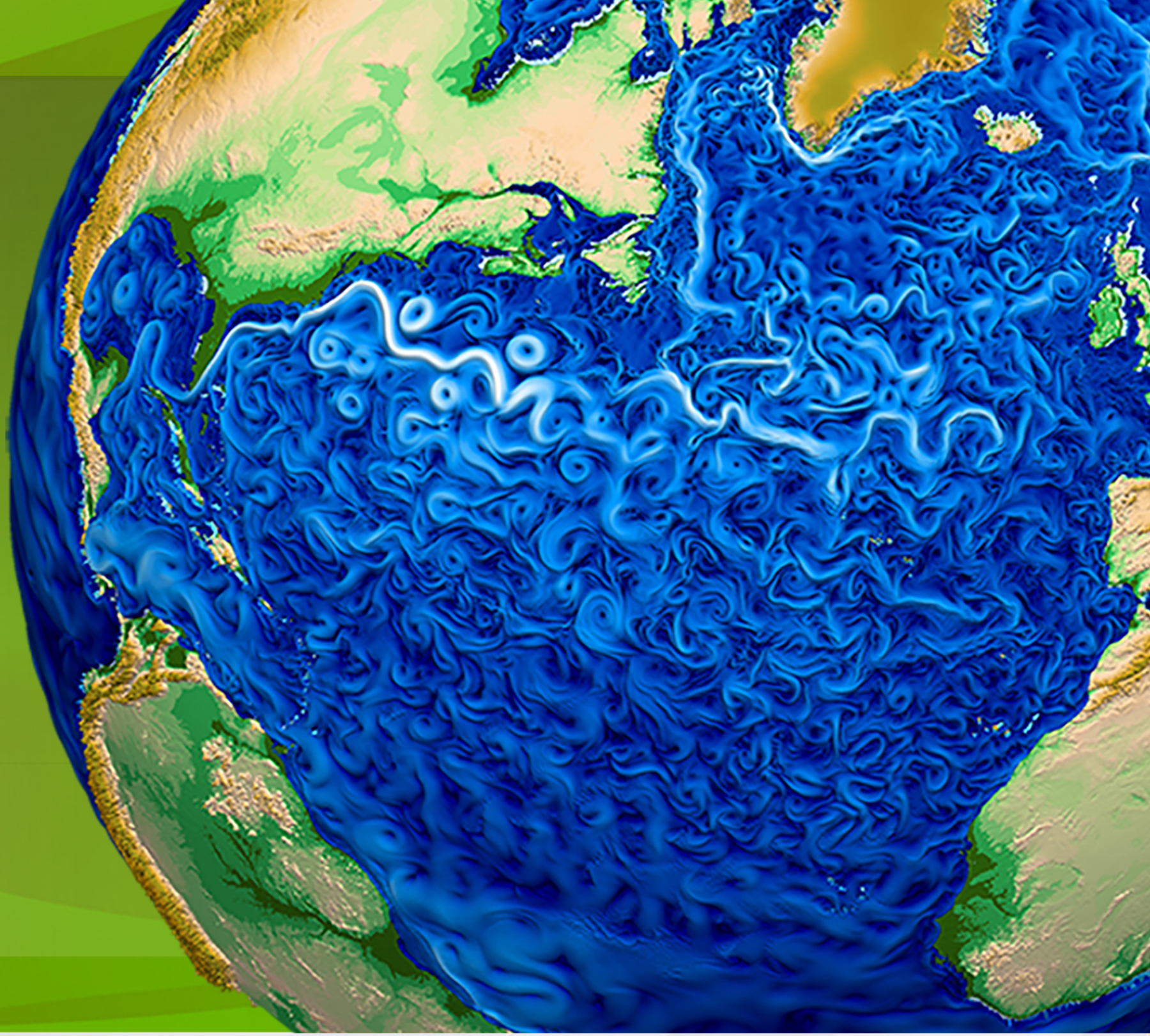
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OM34B-2105: Antarctic ice shelf-ocean interactions in high-resolution, global simulations using the Energy Exascale Earth System Model (E3SM)

Part 1: Configuration and evaluation

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Abstract

Please also see companion poster OM34B-2101: “Part 2: Sensitivity studies and model tuning”.

The U.S. Department of Energy’s Energy Exascale Earth System Model (E3SM) project (formerly known as the Accelerated Climate Model for Energy, or ACME) includes new ocean, land-ice, and sea-ice components using the Model for Prediction Across Scales (MPAS) framework. MPAS provides an unstructured, variable-resolution capability for each of these components, allowing for global, coupled, high-resolution E3SM simulations to be run efficiently on large, high-performance computers. E3SM now includes the ability to simulate ocean circulation in ice shelf cavities. This new science capability is critical for projecting Antarctica’s potential future contributions to global sea level, which is one of E3SM’s primary science drivers. In order to gain confidence in our implementation of ice shelf cavities in MPAS-Ocean, we have performed a series of standard, idealized test cases (see Part 2, poster OM34B-2101). Here we present global E3SM simulations with ice shelf cavities, including CORE-forced and fully-coupled, using a range of model resolutions down to eddy-resolving and enhanced resolutions below ice shelves. Analysis of global simulations are currently focused on validation, using observed sub-marine melt rates and other relevant oceanographic features, and the identification and minimization of coupled model biases.

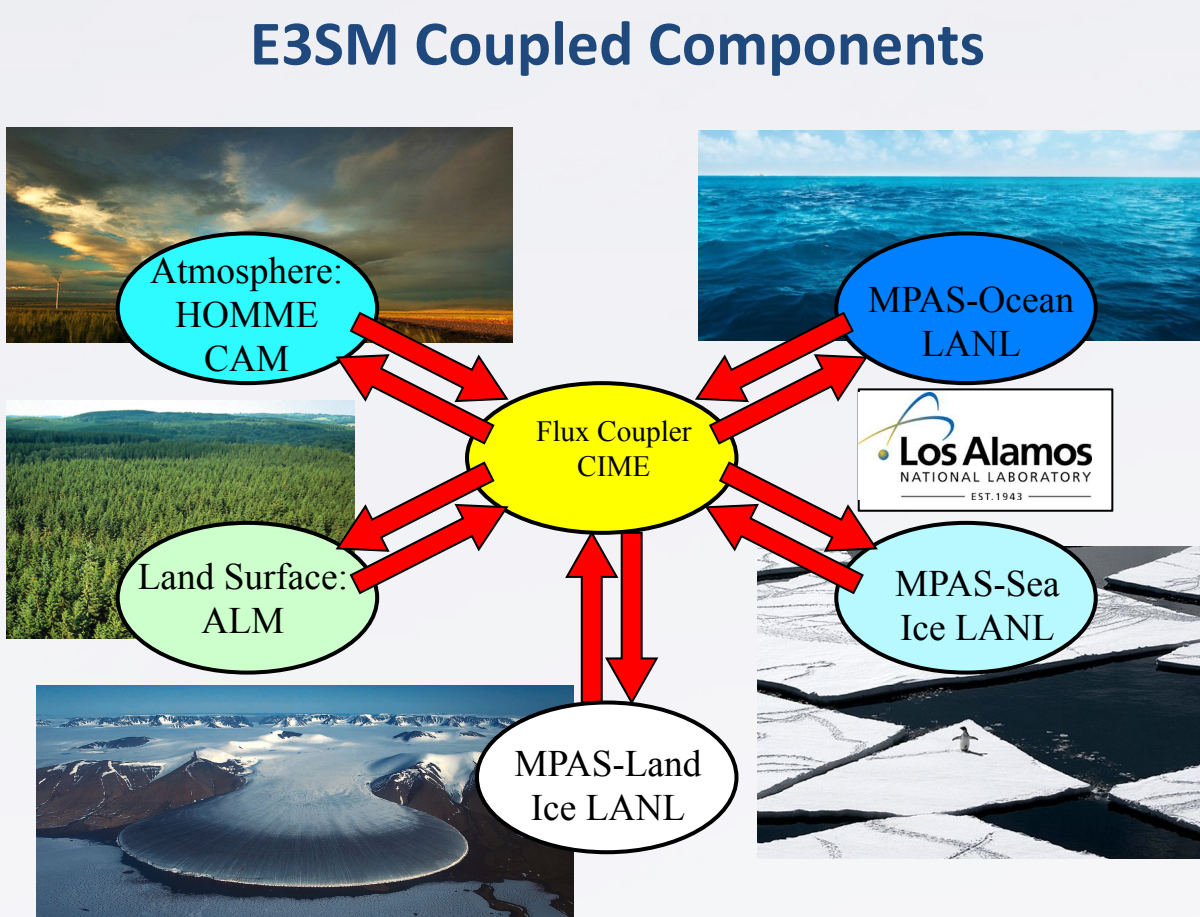
E3SM Simulation Plan

- Resolutions:
- Low resolution: 30 km grid cells below ice shelf, global domain varies from 30 to 60 km (EC60to30)
 - Mid-resolution: 10 km grid cells below ice shelf, resolution varies from 10 to 30 km with latitude in proportion with the Rossby Radius (RRS30to10)

- Atmospheric component:
- Data Atmosphere: Core-II inter-annual forcing (Large and Yeager 2009)
 - Live Atmosphere: Pre-industrial using Homme dynamical core and CAM column physics

- Influence of ice shelf cavities:
- No ocean cavities (standard global domain)
 - With ocean cavities below ice shelves

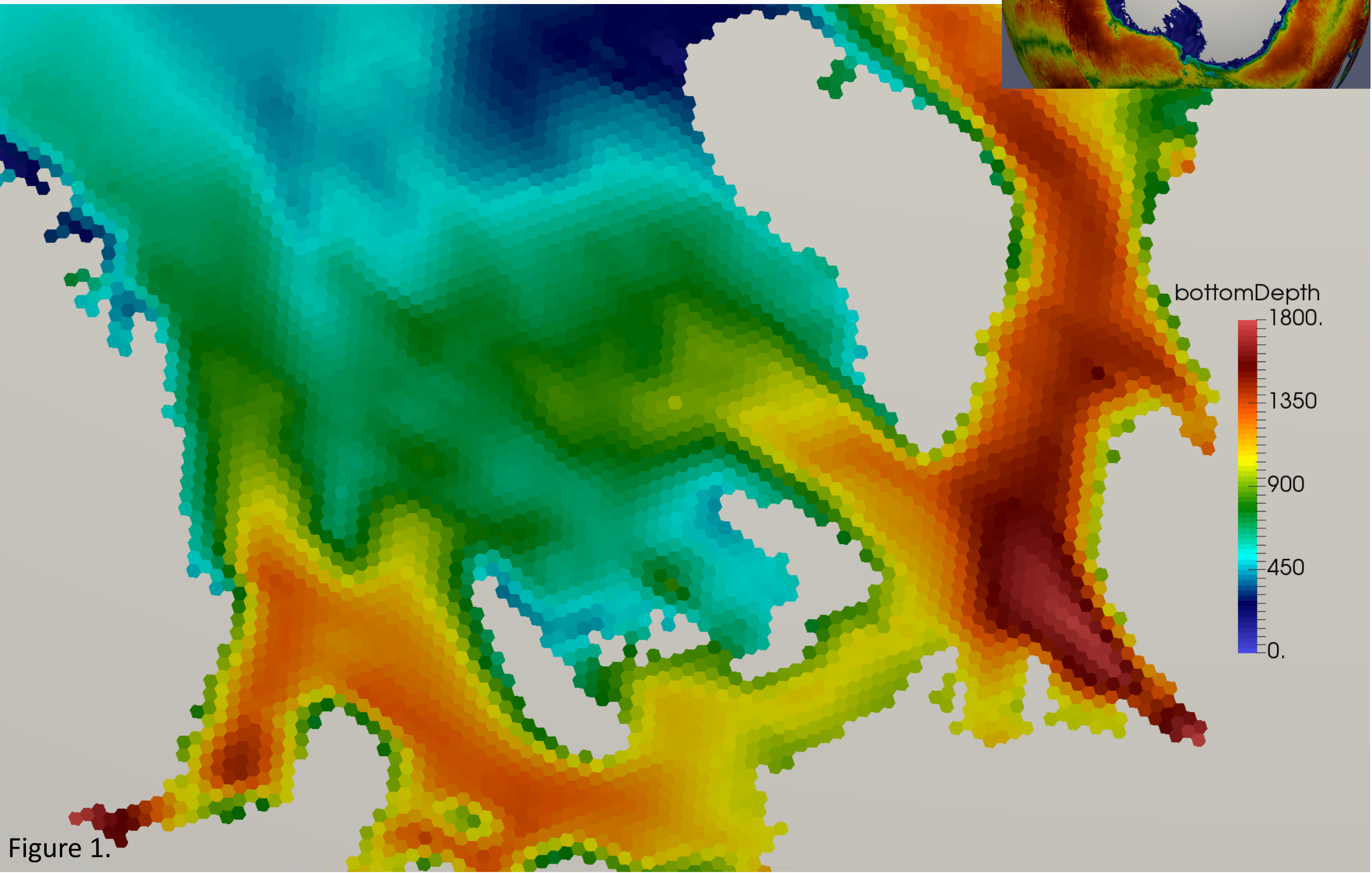
This project was awarded a DOE ALCC computing allocation of 87 million CPU hours for 2017-2018. These simulations use static ice shelves with fixed grounding lines.



Model for Prediction Across Scales (MPAS)

MPAS is a software framework for the rapid development of climate model components on unstructured grids. MPAS variable density grids are particularly well suited to regional climate simulations, and placing high resolution in regions of particular interest.

Mesh for simulations, using 10 km grid cells, mostly hexagons, in Southern Ocean. Zoom of mesh below the Filchner-Ronne ice shelf:



E3SM Simulation Versus Observations

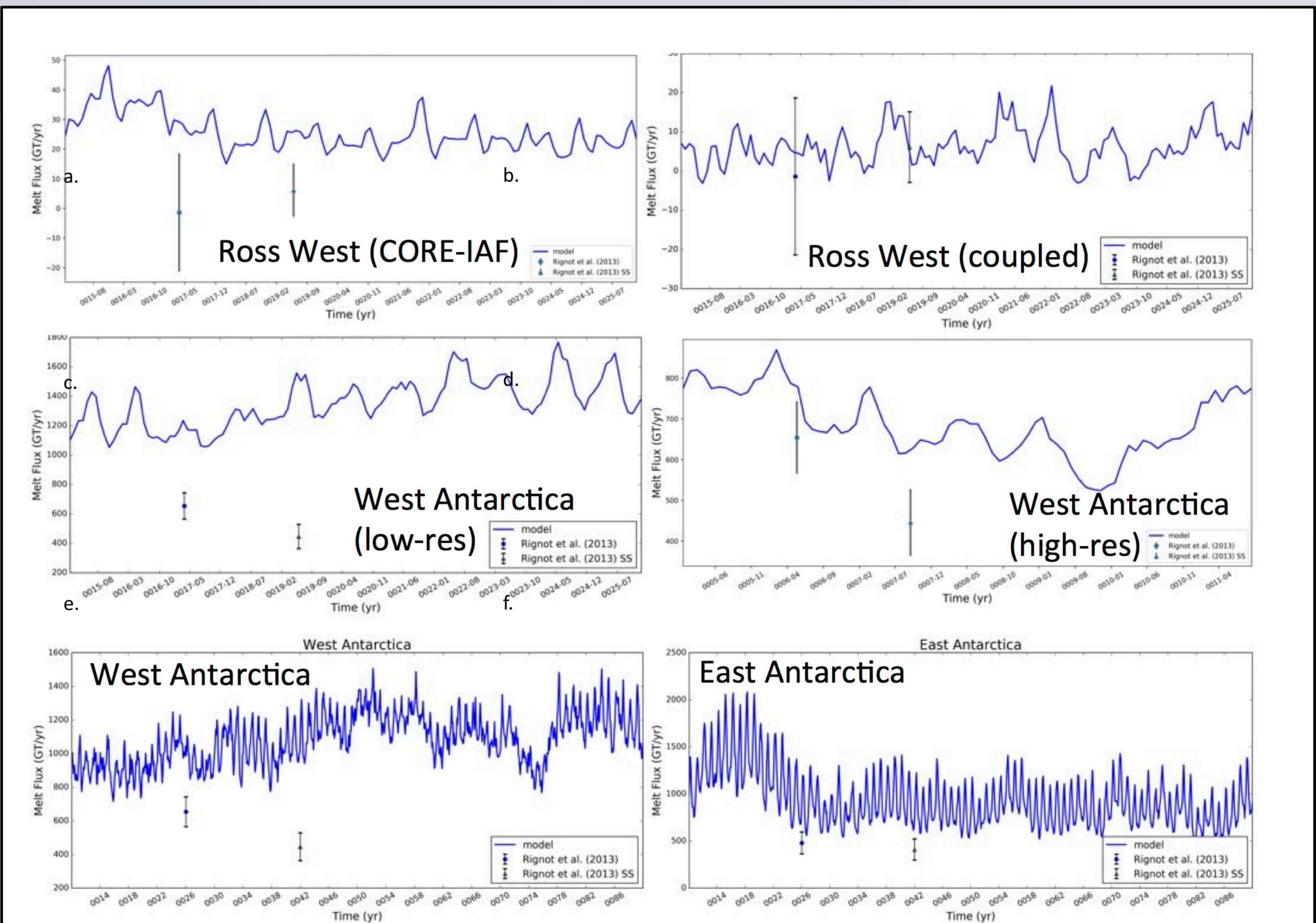


Figure 2. Sub-ice shelf melt flux (Gt/yr) time series demonstrating the impact of coupling and spatial resolution on simulation fidelity. In the top row, output from a fully coupled simulation (b) shows reduced biases relative to a data-forced simulation (a). In the middle row, a simulation using high-spatial resolution (d: 10 km below ice shelves) shows reduced biases relative to a simulation using low-spatial resolution (c: 30 km below ice shelves). In the lower row, a 100-year, fully coupled simulation demonstrates significant inter-annual and decadal-scale variability in sub-ice shelf melt rates. In all figures, observations and error bars are from Rignot et al. 2013. See Figure 4 for region definitions.

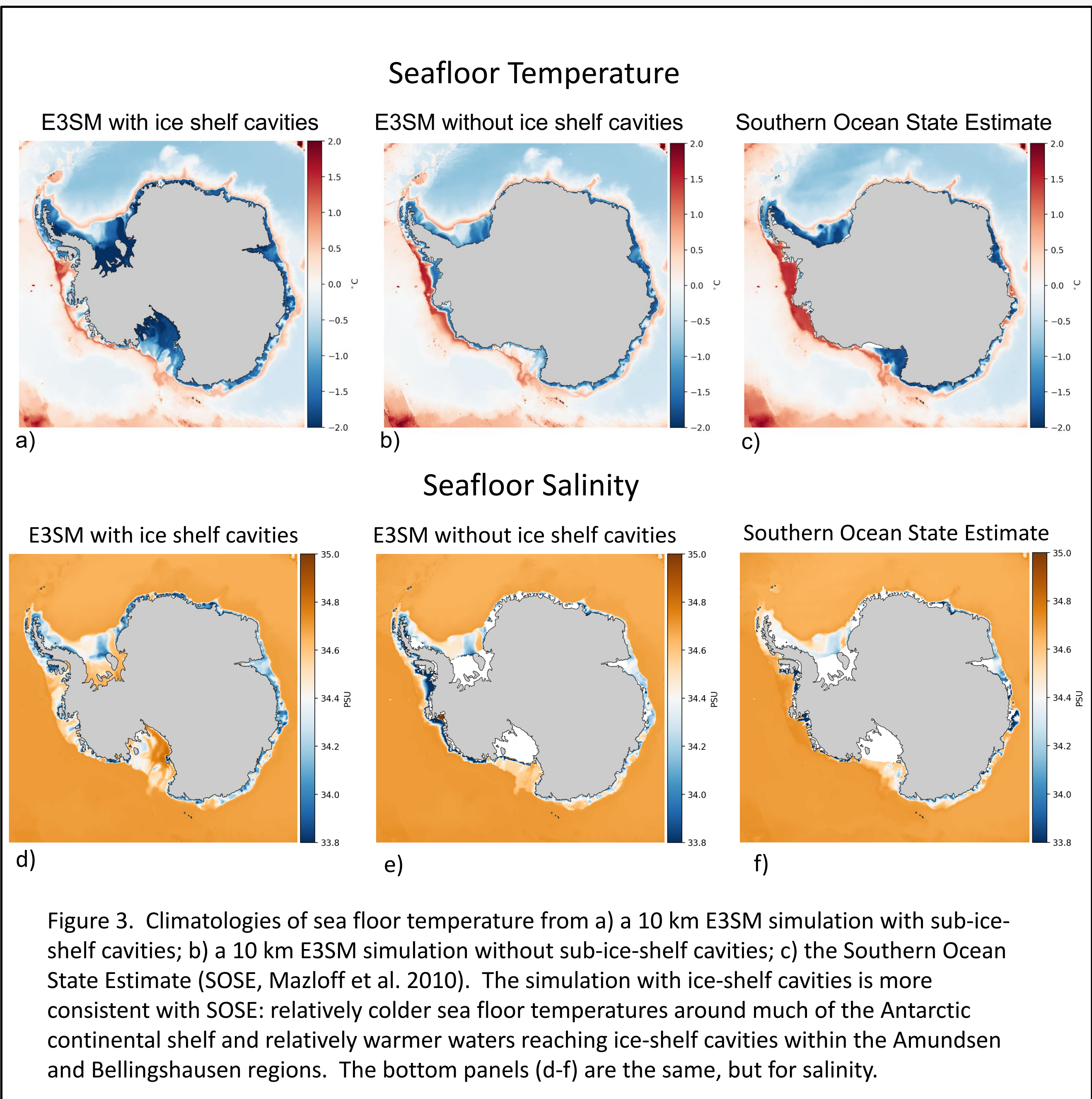


Figure 3. Climatologies of sea floor temperature from a) a 10 km E3SM simulation with sub-ice-shelf cavities; b) a 10 km E3SM simulation without sub-ice-shelf cavities; c) the Southern Ocean State Estimate (SOSE, Mazloff et al. 2010). The simulation with ice-shelf cavities is more consistent with SOSE: relatively colder sea floor temperatures around much of the Antarctic continental shelf and relatively warmer waters reaching ice-shelf cavities within the Amundsen and Bellingshausen regions. The bottom panels (d-f) are the same, but for salinity.

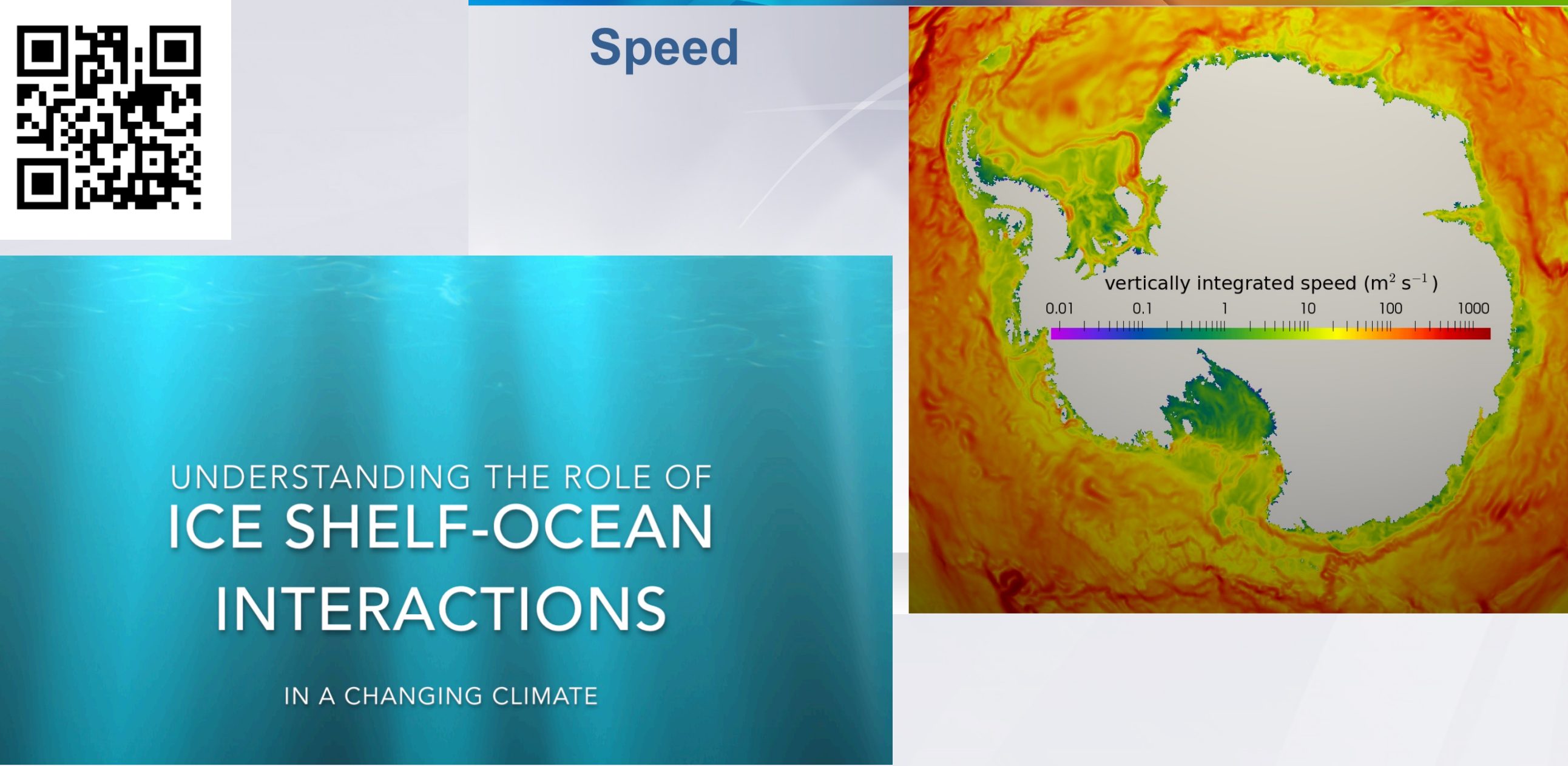
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Documentary Movie

Please see our five-minute video. Scan to view:



Simulations with Active Atmosphere

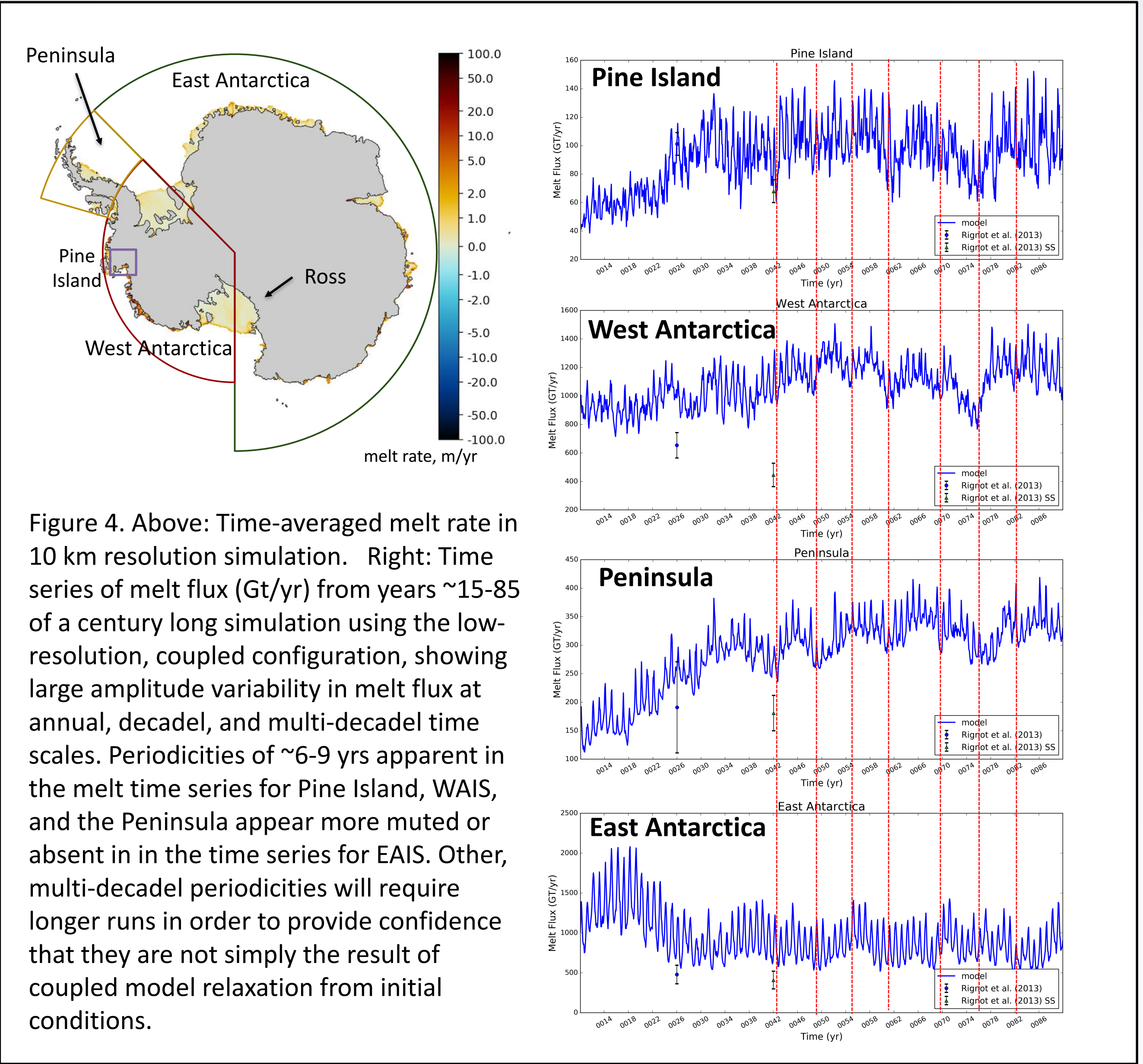


Figure 4. Above: Time-averaged melt rate in 10 km resolution simulation. Right: Time series of melt flux (Gt/yr) from years ~15-85 of a century long simulation using the low-resolution, coupled configuration, showing large amplitude variability in melt flux at annual, decadal, and multi-decadal time scales. Periodicities of ~6-9 yrs apparent in the melt time series for Pine Island, WAIS, and the Peninsula appear more muted or absent in the time series for AIS. Other, multi-decadal periodicities will require longer runs in order to provide confidence that they are not simply the result of coupled model relaxation from initial conditions.

Future Work

- Creation of global mesh with enhanced resolution in Southern Ocean and highly enhanced in ice shelf regions.
- In the long term, transition to dynamic ice shelves, moving grounding line, and coupling to land ice.

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